General Information

Leaflet 11

Energy Efficiency in Offices

"Improving the energy and environmental performance of offices"

BEST PRACTICE PROGRAMME

Energy Efficiency Office
DEPARTMENT OF THE ENVIRONMENT

BEST PRACTICE PROGRAMME

Review of Twelve Office Case Studies

Introduction

This General Information Leaflet reviews twelve of the Energy Efficiency Office's (EEO) Case Studies for energy use in offices. It gives an overview of the buildings and then reviews the general features to reach overall conclusions.

Choice of Case Study Offices

Offices with good all-round energy performance were chosen. In each study, the annual energy consumption and cost were well below the 'Typical' levels given in EEO Energy Consumption Guide 19, for that type of office (see related publications on page 8). Figure 1 shows 'Typical' energy costs for four types of office buildings. In addition, the energy consumption by each for heating, ventilation, air-conditioning and lighting was no higher than the 'Typical' level.

The offices selected not only had their own special characteristics, such as measures to minimise or avoid the use of air-conditioning, but also demonstrated that low energy consumption is just one of the attributes of a carefully-designed and well-managed building.

The Case Studies should be regarded as instructive rather than exemplary and their energy-use profiles should be considered as starting points for new designs rather than targets. By combining the best features from several buildings with even more efficient plant and fittings now available, the energy consumption levels described should be improved.

The results show that an energy efficient office building does not have to be elaborate in design or technology, with the best results coming from a combination of a good initial brief, good design, sound construction, efficient servicing and good management. Techniques and technologies adopted need to be reliable, efficient and understandable. The best designs and control systems pay attention to detail and take account of management and user needs.

For clarity, the Case Study offices are generally classified into the four groups given in the box on this page, although some buildings fall between two of these and are given composite ratings.

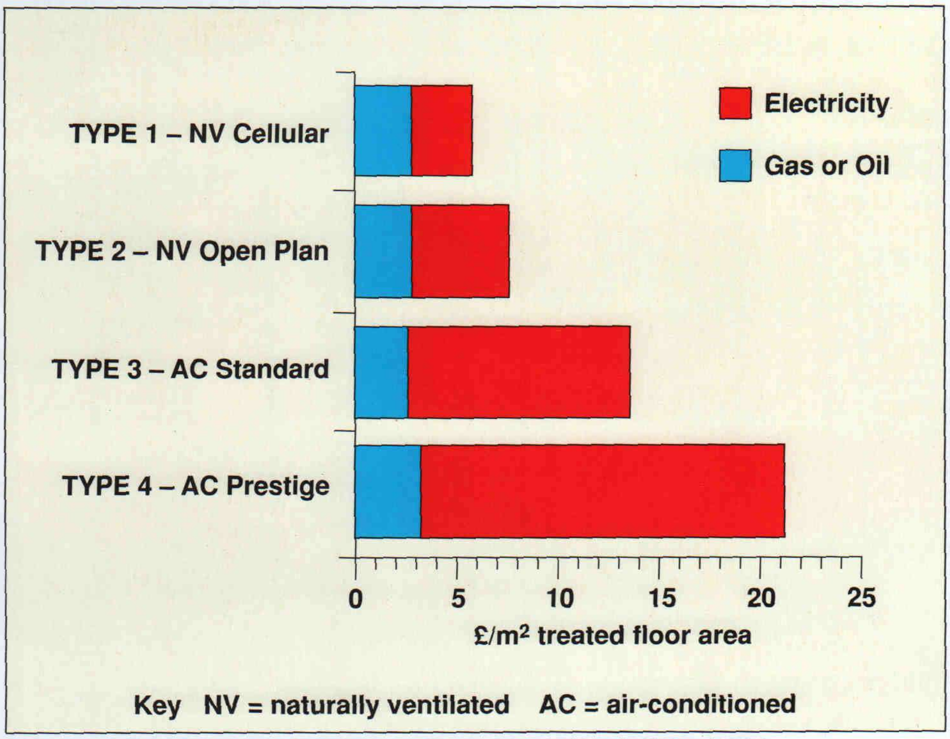

Figure 1 Typical annual energy costs for four types of office building (1991)

The energy consumption of many recently completed or refurbished offices is often much higher than necessary. Over the past decade, energy consumption in UK offices has risen, particularly due to the growth in information technology and more air-conditioning. At the same time, the efficiency of insulation, plant, lighting and control systems has improved considerably, and in principle this should have offset most of the growth elsewhere.

Certainly future energy consumption can be minimised by examining more closely any planned cooling. Air-conditioning systems can be specified needlessly; a more detailed assessment could show that it is not really required.

The heat produced by office technology, for example, is often far less than assumed in cooling system designs, resulting in excessive cooling equipment which operates inefficiently. Further information on this is available in EEO Energy Consumption Guide 35 on small power loads (see page 8).

Unfortunately, recent surveys have revealed limited interest in energy efficiency and its resultant cost savings by owners and occupiers, and little incentive to designers and managers to achieve what is often readily possible. This not only increases needlessly the building's impact on the environment, but can be a symptom of poor business management in other areas. Although energy costs of offices are low in relation to total costs, they are often much higher than necessary and can give some substantial savings.

The Case Studies are intended to raise awareness of the issues and to show the potential for improving the energy and environmental performance of offices. Features of individual buildings are outlined on the next four pages.

Type 1: simple, naturally ventilated buildings mainly of small cellular offices

Type 2: open plan, naturally ventilated buildings tending to use more electricity

Type 3: standard, general-purpose air-conditioned open-plan buildings

Type 4: prestige air-conditioned buildings, such as head offices with restaurant facilities and a computer suite

Naturally Ventilated

BRE LOW-ENERGY OFFICE (LEO)

Good Practice Case Study 62

1950 m^2

80-100 occupants

1984

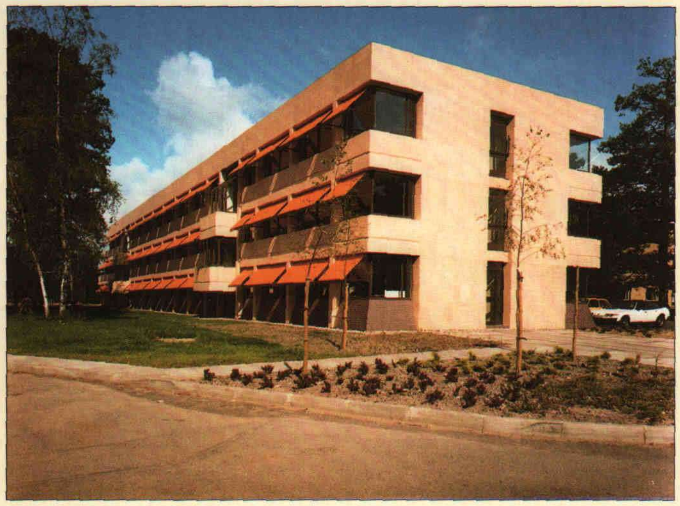

Figure 2

Key Features

- A simple well-insulated cellular office building of average budget
- Designed for low heating and lighting energy consumption
- Good natural lighting
- Thermal capacity and solar protection reduce summertime overheating
- Later upgraded with higher levels of insulation and new electric heating

Discussion

Now ten years old, LEO continues to have good low-energy performance, partly owing to Type 1 cellular characteristics. Two points are of particular importance. Firstly, many features – although fairly simple – did not work as anticipated and needed subsequent alteration. Secondly, the all-electric version had higher energy costs (despite the much-improved insulation) due to the higher unit costs of electricity compared to other fuels.

SOUTH STAFFS WATER Co

Good Practice Case Study 19

2860 m^2

160 occupants

1985

Figure 3

Key Features

- A compact building designed to maximise passive solar heating
- Good natural lighting from low thermal emissivity double-glazing
- Low installed lighting power
- Building energy management system (BEMS) used extensively for controls

Discussion

The good insulation and passive solar features worked well to reduce energy demand for heating and lighting, although glare from low wintertime sun caused a few problems.

However, the total energy consumed was higher than anticipated, owing to shortcomings in system design and operation, and over-complicated controls with a BEMS specification which was too elaborate for a relatively small building.

CORNBROOK HOUSE

Good Practice Case Study 14

2240 m^2

160 occupants

1985

Figure 4

Key Features

- A highly-insulated building to better than 1990 Building Regulations
- Small windows with low-emissivity double-glazing (triple-glazing on noisy flank)
- High-efficiency, gas-fired condensing boilers with independent gas-fired water heater
- Small-scale BEMS controls for heating and ventilation

Discussion

The cost of heating is the lowest of all the naturally-ventilated buildings studied, though not as low as expected. The controls proved to be too complex and not sufficiently user-friendly for a small building without on-site management. Total energy costs could have been lower if the windows had been larger to give more daylight.

Naturally Ventilated

MAGNUS HOUSE

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1290 m²

60 occupants

1988

Figure 5

Key Features

- Low-cost building
- Designed for low heating and lighting energy use
- Largely cellular offices with good daylight and high-frequency lighting
- Domestic-style construction with high thermal capacity and insulation levels
- All-electric heating with close electronic control

Discussion

Energy performance is comparable to BRE's low-energy office with electric heating. On a standardised basis, energy costs and carbon dioxide emissions are relatively high, and the simplicity of electric heating is shown to have a price. However, for a small, well-insulated building in a mild part of the country, electric heating could be more economic on both consumption and cost grounds.

HEMPSTEAD HOUSE

Good Practice Case Study 15

2830 m²

150 occupants

1982

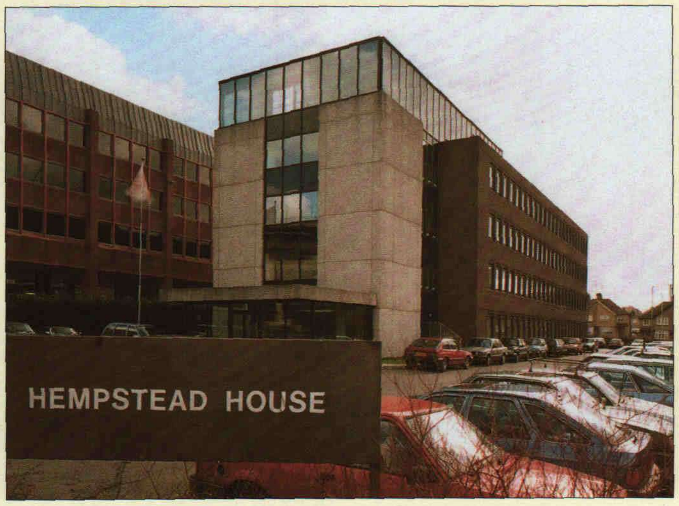

Figure 6

Key Features

- A straightforward speculative building with double glazing
- Well-controlled heating with modular boilers and independent temperature and override control of each floor
- Daylight to stairs and reception
- Uplighting with local and automatic controls on two floors
- Managed by head tenant

Discussion

A speculative, multi-tenanted building, part of which was pre-let to a head tenant who was able to contribute to the low-energy aspects of the design and subsequently manage it. While lighting energy consumption is only average (though improved since the Case Study by changing the uplights to fluorescent), the heating controls work very well, and the electric water heating allows the boilers to be off all summer.

HESLINGTON HALL

Good Practice Case Study 16

4470 m²

150 occupants

Historic

Figure 7

Key Features

- Major reductions in heating and lighting energy use in a listed building by minor alterations and improved plant, controls and management
- High-efficiency gas boiler added to original oil installation to improve part-load performance
- Hot water separated from boilers
- BEMS control from main site system

Discussion

This Case Study illustrates the considerable improvements that can sometimes be made cost-effectively in existing buildings. The changes to the boiler plant were of particular interest.

With the extra capital cost of one relatively small boiler, it was possible to reduce costs overall, make major efficiency improvements, and retain the flexibility and tariff advantages of a dual fuel capability.

SUMMARY OF CASE STUDIES

Air-Conditioned

ONE BRIDEWELL STREET — **Good Practice Case Study 21**

5020 m²

310 occupants

1987

Figure 8

Key Features

- Developer's and occupier's briefs included quality and low running costs
- Concrete external walls with white rainscreen cladding reduce cooling needs
- High frequency lighting with effective central and local control
- Variable air volume air-conditioning at low pressure
- High quality building and energy management assisted by BEMS

Discussion

This building owes its success to a combination of good design, appropriate technology and good management, within the constraints of a sealed, largely artificially-lit, fully air-conditioned building. The fabric is designed to reduce heating and cooling loads and the engineering systems are low-powered, well controlled and very well managed by the head tenant's staff.

QUADRANT HOUSE — **Good Practice Case Study 18**

23 475 m²

1000 average occupants

1980

Figure 9

Key Features

- Improved energy efficiency in an air-conditioned building by improved management and BEMS control
- Use of room heat pumps optimised with occupant control available
- Electricity saved using electronic and local lighting controls
- Summertime electric hot water avoids inefficient use of boilers

Discussion

Air-conditioned buildings can operate wastefully if not well managed. Here, improved control and management, largely financed out of fuel cost savings, reduced gas consumption to one-third and electricity by 15%.

The main savings were from controlling the air-conditioning system carefully, using the primary air plant for the main heating duty and the heat pumps for local trim only.

Naturally and Mechanically Ventilated

POLICY STUDIES INSTITUTE (PSI) — **Good Practice Case Study 1**

2380 m²

80 occupants

refurbished 1985

Figure 10

Key Features

- Low-cost major refurbishment
- Atrium introduced to bring light and air into the core of the building and avoid air-conditioning
- Partial mechanical ventilation with air quality control and solar heat recovery
- Window area reduced and double-glazed but daylight still good in cellular offices

Discussion

The most important feature of PSI is the cutting-in of a new small atrium which met the need for cellular offices within the triangular building without jeopardising a simple and intrinsically lower-energy Type 1 solution.

Gas consumption could have been lowered by replacing the boilers and making the controls for heating and ventilation more accessible.

NFU MUTUAL & AVON GROUP

Good Practice Case Study 13

12 850 m²

600 occupants

1984

Figure 11

Key Features

- A head office planned and designed to minimise any air-conditioning
- Natural and mechanical ventilation with air quality control
- Thermal capacity and solar shading help limit summertime temperatures
- Good daylight with automatic controls and local manual overrides
- Energy management aided by BEMS

Discussion

A staff survey before design started suggested a preference for natural light and ventilation, and the building was designed along these principles, with a courtyard form to maintain a compact plan.

The result is a head office with building services energy costs similar to those of many much simpler naturally-ventilated offices. High ceilings with exposed concrete soffits help to lower summertime temperatures.

HEREFORD & WORCESTER COUNTY (HWCC) HALL

Good Practice Case Study 17

19 750 m²

1050 occupants

1977

Figure 12

Key Features

- Fabric designed to reduce and delay summertime heat gains
- Mechanical ventilation with comfort cooling available in parts but operated only when and where required
- Good natural lighting with manual and automatic controls
- Good energy performance sustained for over ten years

Discussion

An early 'mixed mode' design, with natural ventilation, mechanical ventilation, or comfort cooling selectable to suit management and user needs. Although initially chosen to reduce energy dependency and give some short-term immunity to power cuts, with good energy management the approach has also proved to be a low-energy one. Lighting energy use has recently been reduced with new lamps and reflectors.

REFUGE HOUSE

Good Practice Case Study 20

13 600 m²

700 occupants

1987

Figure 13

Key Features

- Courtyard form avoiding excessively deep spaces
- A head office with both natural ventilation and underfloor fan-coil air-conditioning
- Thermal capacity of structure stabilises temperatures and limits summertime overheating
- High-intensity discharge uplighting with central and local controls
- Comprehensive electronic energy management and controls

Discussion

A courtyard building in some ways similar to NFU but with air-conditioning available throughout, and thus requiring less elaborate window and solar control design. An effective 'mixed-mode' building but with higher lighting running hours than expected as start-up and restrike delays cause the high-intensity discharge uplights to be left on.

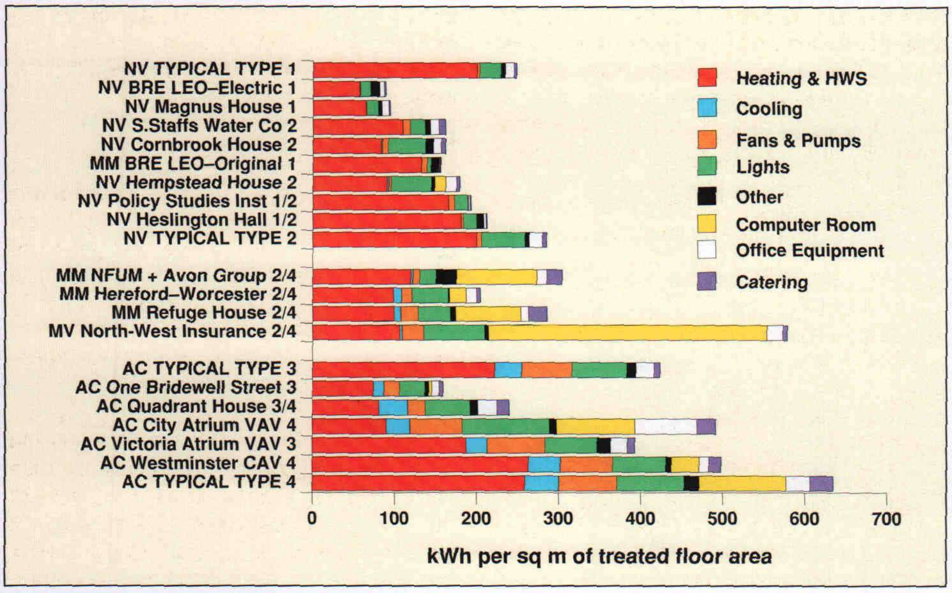

Figure 14 Annual delivered energy consumption

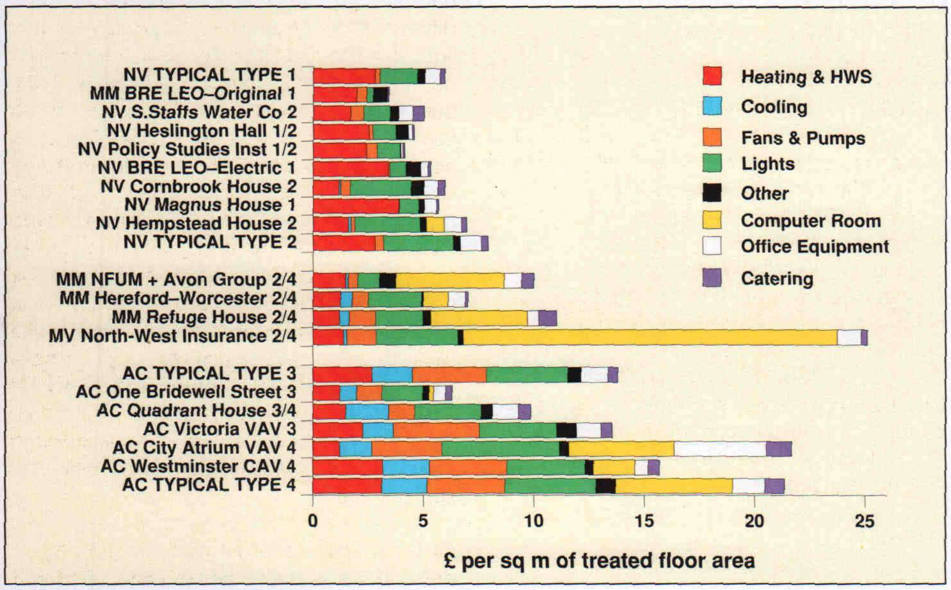

Figure 15 Annual energy cost

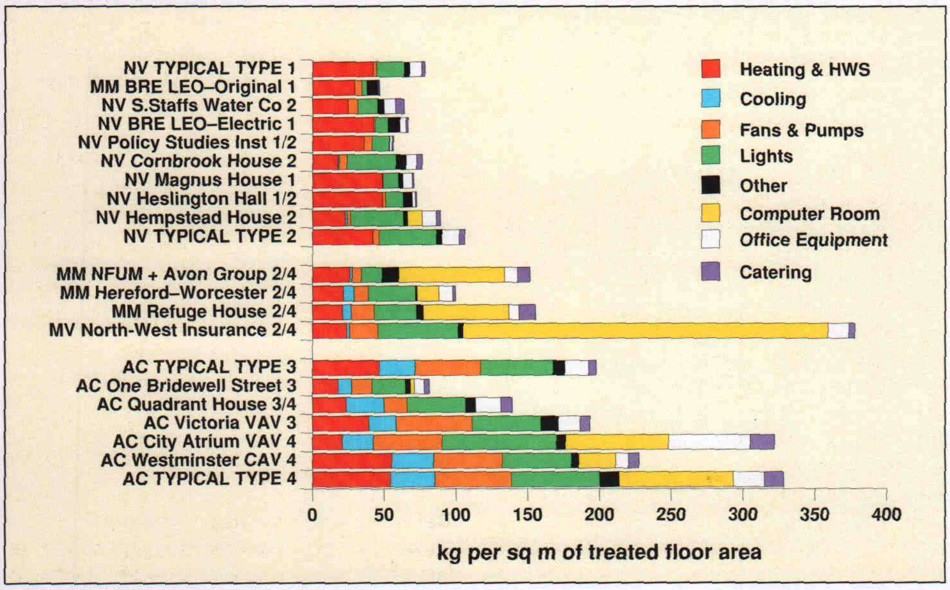

Figure 16 Annual CO_2 emissions

Summary of the Annual Energy Consumption and Cost and the Annual Carbon Dioxide Emissions for each Case Study

The histograms on this page summarise the annual energy consumptions, energy costs and carbon dioxide emissions for the Case Studies reviewed in this General Information Leaflet, with the Building Research Establishment's Low Energy Office – BRE LEO – appearing in both its original gas-heated and its refurbished all-electric forms.

Data for individual buildings is set out between reference data for 'Typical' office buildings of each type.

Four other buildings, considered as possible Good Practice Case Studies, are also included in the histograms under the generic names NW Insurance, Victoria, City Atrium and Westminster. These were subsequently rejected as they did not meet sufficient criteria. At Westminster, although total energy consumption was much lower than average levels due to limited catering and limited use of computers and office equipment, building services energy use was little better than average.

Details have been standardised to 2462 heating degree-days and 1990-91 fuel price levels.

NOTES ON CARBON DIOXIDE EMISSIONS

Each kWh of energy delivered to a building incurs atmospheric emissions of carbon dioxide arising as a consequence of the extraction, processing and delivery of the fuel and its combustion on site. Quoted conversion factors vary according to the assumptions used. The assumptions here in kg CO_2 per kWh of delivered fuel are: Gas 0.21, Oil 0.29, Electricity 0.72.

Key

NV	Naturally ventilated
MV	Mechanically ventilated
AC	Air-conditioned
MM	Mixed mode (A mixed mode building usually combines openable windows with limited mechanical ventilation or cooling)
HWS	Hot water supply
VAV	Variable air volume
CAV	Constant air volume

GENERAL OVERVIEW AND COMPARISON

The range of energy consumptions and costs for the various buildings is large. This reflects not only the underlying characteristics of the different types of office with their various levels of occupancy, servicing and equipment, but also the very wide differences in energy efficiency for different systems and subsystems. Despite the variations, these offices are designed and operated to reasonably consistent good practice. In the stock as a whole, the variations are far wider.

The variations in figures 14 and 15 are interesting. Although the energy consumption and cost of most of the individual categories are in proportion, the heating and hot water supply energy consumption, as a portion of the others, shrinks to a much smaller portion when costs are considered. This is because, in the UK, the average costs of gas or oil – the fuels used predominantly for heating – are typically around one-quarter of that for delivered electricity – the fuel used for nearly all other purposes.

Figures 15 and 16 look broadly similar, and at a practical level annual fuel costs, at current UK rates, can be regarded as roughly equivalent to the associated greenhouse gas emissions. However, in figure 16 the bars for the naturally-ventilated buildings at the top are shorter than in figure 15, but those for the air-conditioned and mixed-mode buildings lower down are of much the same length in both. This is because the larger buildings, and particularly those with large computer rooms operating continuously, generally pay less for a unit of electricity than do the smaller, naturally-ventilated offices with their less uniform load profiles.

The order of the offices also changes when ranked by consumption, cost or emissions associated with normal building services. This largely relates to the fuel used for heating: those burning more gas improve their ranking when assessed for cost or CO_2 emissions rather than for delivered energy while those with electric heating, such as Magnus House and BRE LEO-Electric, move down. This is because the electric heating, although efficiently used and controlled in these highly-insulated buildings, incurs a relatively high average primary energy consumption at the power stations.

Heslington Hall's change in rank order is attributable to its dual fuel boiler plant, which burned a large amount of oil during the Case Study year when oil prices were very low. This saved money but increased CO_2 emissions. Not only were the old oil boilers less efficient, using more fuel than the new gas-fired ones, but their oil-burning created about one-third more CO_2 per kWh consumed.

BUILDING SERVICES SYSTEMS

Heating and hot water

All the Case Study offices use less than typical amounts of heating fuel. This even applies to the Heslington Hall and PSI refurbishments, although both retain and use some old and relatively inefficient boiler plant. This shows that no office of any age should really exceed the currently typical level for its type. A common reason why many do, however, is that the heating plant is not controlled and managed to meet their needs effectively with boilers and pumps frequently running when there is no real demand for them.

The all-electric Case Study offices – BRE LEO-Electric and Magnus House – have well-controlled heating systems and annual energy consumption close to anticipated levels, particularly taking into account the relatively low heat gains from lighting and office equipment.

Of the Type 1 and 2 offices with gas-fired central heating, the highly-insulated Cornbrook House with its condensing boilers performs well, though the fairly ordinary Hempstead House achieves almost the same: a tribute to its simple but carefully considered controls and effective on-site management.

Quadrant House, City Atrium and One Bridewell Street all perform well. The last particularly so given its lower level of internal heat gains. In all these buildings good managers made effective use of Building Energy Management Systems (BEMS). BEMS in the smaller offices, South Staffs Water Co and Cornbrook House, proved too elaborate and simpler controls might have been more appropriate. In air-conditioned offices, fuel consumption depends greatly on effective control and management: systems running wild can waste a lot of energy, as initially at Quadrant House. Even some late 1980s air-conditioned offices use more gas than the typical levels and perhaps three or four times their actual needs.

Cooling

Cooling energy costs and CO_2 emissions are significant in the air-conditioned buildings whilst in the mixed-mode buildings they are considerably smaller – an advantage of this approach. Of the air-conditioned buildings, One Bridewell Street performs well owing to low internal heat gains from lighting, fabric design to reduce solar gains, and good management of plant operation.

Fans, Pumps and Controls

Energy costs and CO_2 emissions are substantial in the air-conditioned buildings, with fans predominating and exceeding refrigeration in all the offices with all-air systems, whether constant or variable air volume (VAV). Air/water systems – such as the heat pump system at Quadrant House – have lower-volume air supply systems and tend to use considerably less energy for fans, more for the chillers, and slightly less overall. Fan energy costs surprise many people who see efficient air-conditioning as predominantly about refrigeration efficiency, and many air-conditioned offices use considerably more than typical levels. Pressure drops, hours of use and air volumes handled need to be as low as possible. This need not be at the expense of air quality for often air can be handled and rooms ventilated more efficiently than at present.

Lighting

Lighting energy costs can be high and also very variable, both within as well as between types. Type 1 offices tend to be the lowest consumers as effective control and good use of daylight is relatively easy with individual rooms and switches at the door. In BRE LEO-Original, the lighting values were typical as occupancy was very low at the time – LEO-Electric is a better reference.

In spite of this, further improvements could be made. LEO's lighting is now over ten years old and, if replaced by new, efficient fittings, could achieve a 30% saving. In Magnus House, the illumination level at 700 lux is about twice that needed by most occupants.

In open-planned offices, usable glare-free daylight and effective light switching is more difficult to achieve. Without careful attention lights tend to stay on for the working day and beyond. Automatic lighting controls can help, but need careful design and management to succeed. The most successful Case Studies to combine natural light, automatic controls and local manual overrides are SSWC and NFU, but both still have scope for improvement. At SSWC local switching via the BEMS introduced irritating time delays whilst the corridor lighting, with long running hours, could also have been more efficient. NFU would have preferred each light fitting to have been individually switched and remotely addressed as was not practical at the time of design. At both, low winter sun through high level windows sometimes causes VDU screen glare.

Of the offices largely reliant on permanent artificial lighting, One Bridewell Street performs very well, for four main reasons.

- It uses modern high-frequency fluorescent fittings with good reflectors, which use 11 W of installed power per square metre of office floor area: many similar offices use 15-20 W/m^2 for the same result.
- Local control is by hand-held infra-red devices. These paid for themselves eliminating the need for switch drops and for wiring alterations when partitions were installed and changed.
- The lights are also switched-off automatically by a system programmed, to take full account of user needs.
- The atrium and main circulation is well-lit naturally. Low-energy lamps are used in internal stairs, toilets, etc.

Catering and Vending

The lowest energy consumers only had casual facilities with local kettles whilst the next had vending machines. These can use significant

amounts of electricity, especially if left on 24 hours per day. The highest consumers, not surprisingly, were NFU, Refuge, Quadrant House and City Atrium with their kitchens, restaurants and private dining facilities serving one daily meal for half or more of their staff. The following points are of interest.

- The high cost at City Atrium arises because it has four separate all-electric kitchens to suit the needs of different tenants.

- The low cost at Quadrant House arises because its occupancy by a large number of commonly-serviced small publishing units lends itself to a continuous through-the-day service – allowing the kitchen equipment to be used more intensively and efficiently. More cold meals were also served.

Apart from Quadrant House, none of the kitchen operations seen was particularly energy efficient: occupiers normally make kitchen energy supplies freely available at no charge, giving no incentive to catering contractors either to invest or to manage for energy efficiency.

Consideration should be given to metering energy supplies to kitchens and charging the operators for energy (and indeed also for water) consumed.

Office equipment

The energy used by office equipment was relatively low and in total considerably less than lighting, except at City Atrium, a financial trading office with large dealing rooms and considerable early morning, late evening and weekend work.

Since the Case Studies were completed, the use of electronic office equipment has grown, particularly in Type 1 and 2 offices, which tend to have been rather later in the uptake of the technology. This has increased equipment energy consumption in the simpler offices. However, in offices which made intensive use of IT earlier, such as City Atrium, IT consumption has tended to stabilise and even to fall as new equipment requiring less energy, replaces the old.

Measurements during the studies suggested energy consumption and cooling load estimates based on manufacturers' ratings could be misleading. The average piece of equipment when running in normal use consumed typically about one-third of the power one might infer from catalogue or nameplate data, although the actual figure varies widely with device and manufacturer. This can have a significant affect on the design of cooling systems, and can lead to a substantial waste of energy.

Computer rooms

The high energy consumption of some computer suites and their associated air-conditioning sometimes gives as much surprise as the relatively low consumption of office equipment. People seem to forget the effect of hours of use for systems which run continuously year-round.

All three owner-occupied buildings with computers had made efforts to save energy with their computer air-conditioning. NFU's swimming pool was heated at low cost using the absorbed heat. At Refuge, the refrigeration could be switched-off in cold weather and the chilled water cooled by outside air – a feature abandoned when the computer was enlarged. At NW Insurance, gas consumption was halved by warming the offices with the excess heat.

However, in many computer rooms considerable energy savings can be made without going to such lengths. Conventional air-conditioning can often be made considerably more efficient by attention to design, control and management. Electricity supplies to mainframe computer rooms and their air-conditioning should each be separately metered and checked to make sure they are performing as well as possible.

Good computer air-conditioning need not use more than about 60% of the electricity used by the computer – some systems consume two or three times as much!

Other items

In all offices, there is also a group of miscellaneous items consuming energy although the amount is usually only a small proportion of the total. These include lifts, external lighting, ventilation and lighting for underground car parks and, in specific Case Studies also include:

- at BRE LEO – the permanent equipment monitoring the building's performance

- at NFU – ventilation, water treatment, auxiliary heating and pumping for the swimming pool, and

- at Victoria – continuous air-conditioning and lighting in the atrium for the benefit of the vegetation. This occurs in many atria and should be avoided by appropriate design of the services and selection of planting.

CONCLUSIONS

Energy efficiency in offices is not only, or even mainly, about heating: electricity costs usually predominate. Most of the Case Study buildings are fairly straightforward, and their low consumption is a product of good design, good building and appropriate technology. Good management becomes especially important in the more complex and highly-serviced buildings which in turn require good feedback information from controls, well-placed sub-meters, and occupants.

For heating, better insulation is not the whole story. The system also has to be well-designed, controlled and managed to avoid overheating and ensure efficient operation without avoidable waste.

In air-conditioned offices, the fans often cost more to run than the chillers, and excess running hours often lead to unseen – and often undetected – waste. Again, good, user-friendly controls and good management is essential.

Lighting is often the largest single item of energy cost, varying over a wide range depending upon installed power and hours of operation. Efficient installations and good, user-friendly controls should be the norm.

Although office equipment may use less energy than people expect, leaving it on unnecessarily, and particularly overnight, should be discouraged. When purchasing, energy demands should be taken into account, as some brands and types of equipment use considerably less energy than others. The design and management of air-conditioning for mainframe computer suites should also be carefully considered.

Controls generally have to be appropriate for the task in hand and the management skills available. Advanced electronic controls and BEMS must be seen and designed as tools to aid good management, not as substitutes for it: if they are too obscure or complex for the time and skill available, they are likely to become a barrier rather than an asset.

RELATED STUDIES AND GUIDES under the BEST PRACTICE PROGRAMME
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1 Policy Studies Institute
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14 Cornbrook House
15 Hempstead House
16 Heslington Hall
17 Hereford and Worcester County Hall
18 Quadrant House
19 South Staffordshire Water Company
20 Refuge House
21 One Bridewell Street
39 Condensing Gas Boilers for heating and hot water in offices
62 BRE Low Energy Office

General Information Leaflets
10 Magnus House
12 Posford House, Peterborough

Other Unpublished Cases Investigated
NW Insurance, Victoria, City Atrium

Good Practice Guides
16 Condensing boilers in commercial buildings
33 Understanding Energy Use in Your Office
34 Energy Efficient Options for New Offices
35 Energy Efficient Options for Refurbished Offices
46 Energy Efficiency in Offices: Heating and Hot Water Systems

Energy Consumption Guides
10 Energy Consumption Guide for Senior Managers
19 Energy use in offices: a Guide for owner-occupiers and single tenants
35 Small power loads in offices

All Case Study analyses are based on at least one year's measured fuel consumption and costs.

The co-operation of the owners, designers, managers and the occupants of the Case Study buildings is gratefully acknowledged.

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